Performance Analysis of OCDMA System with Unipolar Walsh Coding

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Abstract

The success of a radiofrequency in CDMA depends on well designed bipolar codes with good correlation properties. These sequences of (+1, -1) values exist in the RF domain because the phase of the electromagnetic field can be detected directly. The unipolar optical coding is studied as optical system is nonnegative and unipolar in nature and detects and processes the signal intensity. The strict orthogonality of bipolar Walsh codes shows cross correlations to be equal to zero while auto correlations have large magnitudes. Unipolar Walsh coding have been studied and constructed in the previous published papers. In this work, the performance of the proposed codes has been analyzed and it has been observed that performance is better than modified frequency hopping & Hadamard code, Random Diagonal codes. Theoretical results for SNR and BER and Simulation results are shown.

Keywords

Optical Code Division Multiple Access; Unipolar Codes; Orthogonal Codes.SNR; Bit Error Rate

Introduction

Nowadays, the most attractive technique in optical communication which draws attention for high capacity multi-access local area network is Optical Code Division Multiple Access (OCDMA) with many outstanding advantages such as large capacity, high security and excellent anti-interference ability, making OCDMA a much suitable technique of research in optical communication system. In wireless network, CDMA has been widely used as multichannel access for several years because of its low interference effect. However, its application in optical medium becomes more attractive due to the large bandwidth of optical fiber. The advantages of CDMA are i) no required timing synchronization ii) no need for wavelength control iii) effective utilization of bandwidth iv) high tolerance to noises v) inherent security vi) simple hardware.

Optical Code Division Multiple Access (OCDMA)

technique is a prime solution for optical network since it allows many users to access the network asynchronously, simultaneously and provides flexible and secure transmission. Theoretical analysis of optical CDMA systems has shown that multiuser interference (MUI) is the main reason for performance degradation, especially when large numbers of users are involved. In spectral-amplitude-coding optical CDMA systems given a user number and a code length, MUI is only determined by the values of in-phase cross correlation (CC) between the address sequences. Several codes like Optical Orthogonal codes(OOCs) (Chung F., Salehi J., and Wei V, 1989, Jawad.A.Salehi, Charles A. Brackett, 1989), prime codes(Shaar, A. A., & Davies, P. A., 1983, Prucnal, P., Santoro, M. A., & Sehgal, S. K,1986)[, Modified Frequency Hopping codes , Hadamard codes(Wei, Z., H., Shalaby, M., & Shiraz, H. G.,1986) Random Diagonal codes(Hilal Fadhil, Syed Aljunid, and Badlished Ahmed ,2010) have been proposed for OCDMA. However, these codes have limitations e.g. OOC and MFH codes are complicated to construct, Hadamard and Prime codes have poor cross-correlation properties also for OOC and Prime code length are too long.

Various coherent OCDMA systems have been implemented to overcome these limitations. In our work for unipolar Walsh code, a broad band source has been modulated.

The paper has been organized as follows: section I briefly discusses about our coding system, section II describes the performance of the system in comparison to other, section III provides the OCDMA system and the simulation results in finally section IV gives conclusions.

Code Construction

In our previous papers (Somali Sikder and Shila Ghosh, 2012) the details of the unipolar Walsh code construction have already been discussed. For a

bipolar Walsh matrix

$$W_{2N} = \begin{vmatrix} W_N & W_N \\ W_N & {}_-W_N \end{vmatrix}$$

Where-W_N stands for complement of W_N. Here W1 =[1]

In this implementation of the unipolar codes, the correlation properties of the bipolar codes are completely preserved. In bipolar equivalent encoding for unipolar channels, for each length N bipolar code X, a unipolar sequence is formed replacing -1 to 0. The concatenation of Y and its complement Y can form a unipolar super code J of length 2N. For spectral amplitude encoding considering, the second row of Walsh code W_4 the sequence is X (=1-1 1-1). Therefore, in unipolar form, the sequence becomes 10100101. The bipolar and unipolar form of X are shown in Fig1 (a) and Fig 1(b), respectively.

As a result the Unipolar Walsh code becomes:

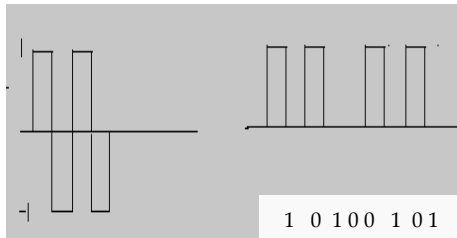$$W_{4U} = \begin{vmatrix} 11110000 \\ 10100101 \\ 11000011 \\ 10010110 \end{vmatrix}$$

FIG. 1 POLAR FORM OF SEQUENCE

a) Bipolar form(X); b) Unipolar form (J)

In this coding system, 1 is replaced by 10 whereas 0 is replaced by 01.

Theoretical Performance Analysis

A (N, W, λa, λc) optical orthogonal code is a set of (0,1) sequences of length N and weight W (the number of ones in every codeword). Here λa is the autocorrelation and λc is the cross-correlation between two different code sequences[6,7]. In the analysis of the proposed system, incoherent intensity noise has been taken into consdieration, as well as shot and thermal noises. The effect of the receiver's dark current is neglected. Gaussian approximation is used for the calculation of BER. The variance of photocurrent due to the detection of an ideally unpolarized thermal light, which is generated by spontaneous emission, can be expressed as

$$\langle i^2 \rangle = 2eIB + I^2 \tau_c B + \frac{4KTB}{R_L}$$

Where, e=electron's charge; I=average photocurrent; B= noise-equivalent electrical bandwidth of the receiver; τ_c=coherence time of source; K=Boltzmann's constant; T=absolute receiver noise temperature; R=receiver load resistor.

TABLE I

Single source Power at Receiver	P_{sr} =10mW
Photo detector quantum efficiency	η=0.8
line width of the thermal source	ΔV=2.5THz
Operating wavelength	λ=1.33μm
Electrical bandwidth	B=80mhZ
Receiver noise temperature	T=300K
Receiver load resistor	R_L =1K

Table1-Typical parameters used in the calculation

The parameters used in our analysis are listed in Table1. In the above equation, the first term results from the shot noise, the second term denotes the effect of the phase-induced intensity noise (PIIN) and the third term represents the effect of thermal noise.

Now let c_k denote the code sequence of kth row of an KxN unipolar Walsh matrix.

The code properties can be written as:

$$\sum_{i=1}^{N} ck(i) * cj(i) = \frac{N}{4}, k \neq j \text{ and } \frac{N}{2}$$

when k=j Where $ck(i) = \frac{[1 + wk(i)]}{2}$

$w_k(i)$=bipolar Walsh code matrix of kth row. K=number of active user and K<= N. In this case weight of the code W=**N/2**;

Therefore the expression of SNR can be written as (Z. Wei, H. M. Shalaby, and H. Ghafouri-Shiraz, 2001)

$$SNR = \frac{\left[\frac{RP}{N1}\right]^2}{\frac{BR^2 P_{sr}^2 K\left[\frac{K-1}{N1} + N1 + K\right]}{2\Delta V N1^2 \frac{N}{2}} + eBRP_{sr}\frac{[N1 - 1 + 2K]}{N1\frac{N}{2}} + \frac{4KTB}{R_L}}$$

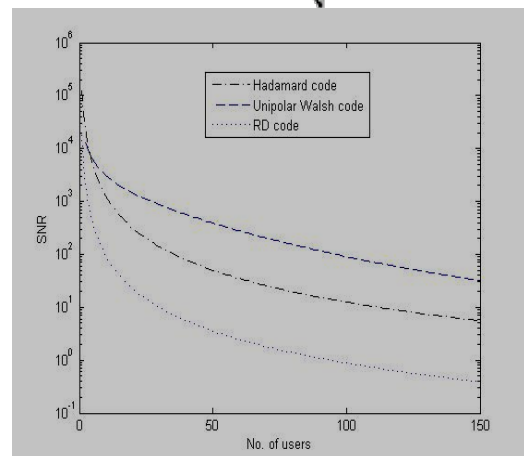Corresponding $BER = 0.5 erfc \sqrt{\frac{SNR}{8}}$
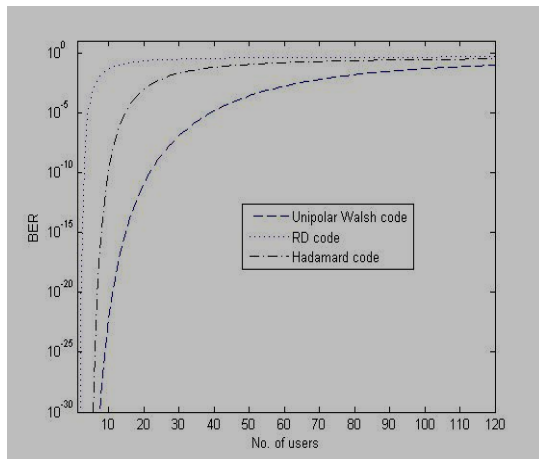

FIG. 2 SNRS VERSUS NUMBER OF SIMULTANEOUS USERS

FIG. 3 BERS VERSUS NUMBER OF SIMULTANEOUS USERS

Using the general SNR and respective BER equation for unipolar Walsh code, Figure 2, 3 depict the relation between the number of users and the BER/SNR, for RD code (Hilal Fadhil, Syed Aljunid, and Badlished Ahmed, 2010), Hadamard code(Wei, Z., H., Shalaby, M., & Shiraz, H. G.,2002)where they have been plotted for different values of K (number of users).

The above figure clearly shows that unipolar Walsh code results in a much better performance, i.e., smaller BER than Hadamard code and RD schemes. This is evident from the fact that unipolar Walsh code has a zero cross-correlation while Hadamard code has increasing value of cross correlation as the number of users increases. The correlations are calculated using the formula (K Yang,Y.Ky Kim & P.V.Kumar,2000) correlation =length -2. $*H_d$ Length stands for the length of the code and H_d= Hamming distance among the codes. It has been observed that the cross-correlation among the codes is zero whereas the autocorrelation among them is about 2* K.

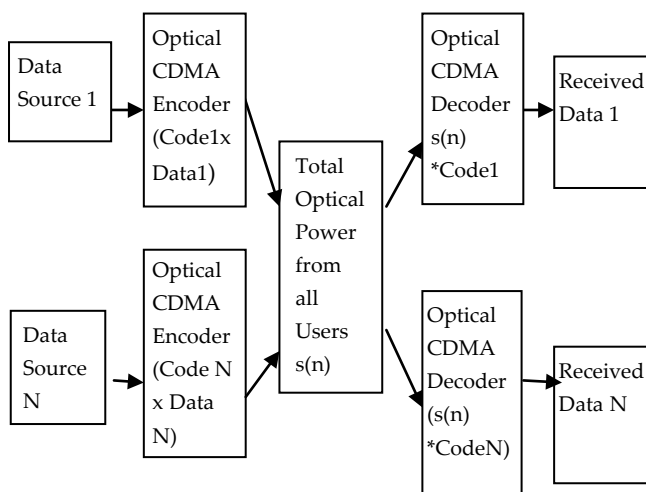## OCDMA System and Simulation Result

FIG. 4 BLOCK DIAGRAM OF GENERIC ARCHITECTURE OF CDMA SYSTEM

The architecture (Behrouz A Forouzan, 2006) of the optical CDMA system using unipolar Walsh code is shown in Figure 5. Each of the user data will be encoded with a different OCDMA code word and transmitted to all the receivers.

s1, s2…are regarded as the users in a network having its own sequence code c1, c2…corresponding to rows of Walsh table. At the time of transmission, data of each station is multiplied by the corresponding sequence code of that particular station. The sequence for common optical transmission channel is found out by adding sequences of all stations. For decoding the receiver station multiplies the channel data with the code of the sender (Behrouz A Forouzan, 2006).

Here the received data is obtained by multiplying the transmitted data sequence with respective CDMA code and dividing the result with the no. of stations (users). The user will be considered as 1 if the resultant value exceeds some threshold value. The above architecture has been simulated (Wei, Z. & Shiraz, H. G., 2002) using OPTIWAVE Simulation tool. The figure below shows a particular transmitted and received data for a specific code pattern when a user sending 1.
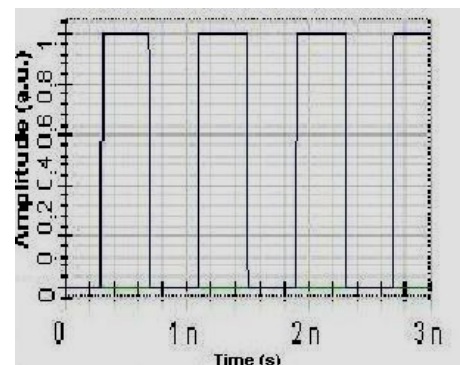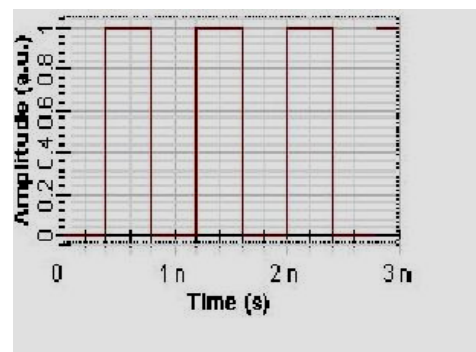

FIG. 5a TRANSMITTED DATA

FIG. 5b RECEIVED DATA AFTER SIMULATION

Conclusion

It can be observed that the performance of unipolar Walsh codes is much better compared to other codes. Unipolar Walsh code can effectively suppress the

effect of intensity noise and, hence, resulting in a much better performance. This suppression, in fact, comes from the lower in-phase cross correlation of unipolar Walsh codes. The limitation of unipolar Walsh codes is that it has large code length although a higher autocorrelation due to its weight, which is half of the code length.

REFERENCES

Behrouz A Forouzan, Data Communications and networking, Chapter 12, Tata McGraw Hill , New Delhi, 2006

Chung F., Salehi J., and Wei V., "Optical Orthogonal Codes: Design, Analysis and Applications," IEEE Transactions on Information Theory, Vol. 35, No. 3, pp. 595–604, 1989.

Djordjevic I. and Vasic B., "Combination Construction of Optical Orthogonal Codes for OCDMA Systems," IEEE Communications Letters, Vol. 8, No. 6, 2004.

Hilal Fadhil, Syed Aljunid, and Badlished Ahmed. "Performance of OCDMA Systems Using Random Diagonal Code for Different Decoders Architecture Schemes." The International Arab Journal of Information Technology, Vol. 7, No. 1, January 2010

Jawad.A.Salehi, Charles A. Brackett, "Code Division Multiple Access Techniques in Optical Fiber Networks-Part II: Systems Performance Analysis" IEEE Transactions on communication, Vol. 37, No.8 August 1989.

Keiser G., "Optical Communication Essentials", McGraw-Hill, 2003.

K Yang, Y.Ky Kim & P.V. Kumar "Quasi-orthogonal sequences for code division multiple –access systems", IEEE Transactions on Information Theory, Vol. 46, No. 3, pp. 982–985,May 2000

Lim Nguyen, Tasshi Dennis, Behnaan Aazhang and James F. Young, "Experimental demonstration of bipolar codes for optical spectral amplitude CDMA communication", Journal of Light wave Technology, Vol. 15, No.9, pp.1647-1653, September 1997.

Prucnal, P., Santoro, M. A., & Sehgal, S. K. "Ultrafast all-optical multiple access fiber networks." IEEE J. Selected Areas in Communications, 4 (9), 1484-1494,1986.

Shaar, A. A., & Davies, P. A. "Prime sequences: Quansi-optimal sequences for OR channel code division multiplexing" Electronic letters, 19(12), 888-890,(1983).

Wei, Z., H., Shalaby, M., & Shiraz, H. G. New code families for fiber-brag-grating-based spectral-amplitude-coding optical CDMA systems. IEEE Photonics Technology Letters, 13, 890–892,2001.

Shila Ghosh & B.N. Chatterji "Theoretical study of use of optical orthogonal codes for compresses video transmission in optical code division multiple access (OCDMA) systems", Proceedings of International Conference on Photonics & optical Engineering, California, 2007.

Somali Sikder and Shila Ghosh, " Study of Bipolar Walsh Coding in Optical Code Division Multiple Access (OCDMA) System", Proceedings of National Conference on Materials, Devices and Circuits in Communication Technology ,IETE Burdwan Sub Centre, University of Burdwan, India,Feb 6-7 ,2012,pp.200-203.

Wei, Z. & Shiraz, H. G.Code for spectral-amplitude-coding optical CDMA systems. J. Lightwave Technol., 20, 1284-1291,2002.

Z. Wei, H. M. Shalaby, and H. Ghafouri-Shiraz, "Modified quadratic congruence codes for fiber bragg-grating-based spectral amplitude-coding optical CDMA systems," J. Lightwave Technol., vol. 19,2001.

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